GRAPPA Anisotropy Workshop

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Anisotropic Orientations of Polarisations from Quasar Light

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in collaboration with J.-R. Cudell

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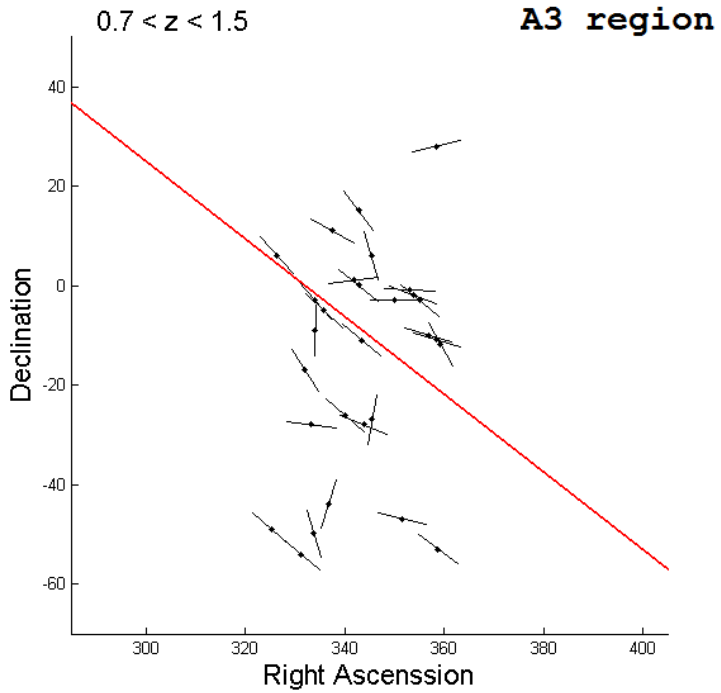
Liège University (Belgium)

Introduction
The large-scale coherent orientations of quasar polarisation vectors



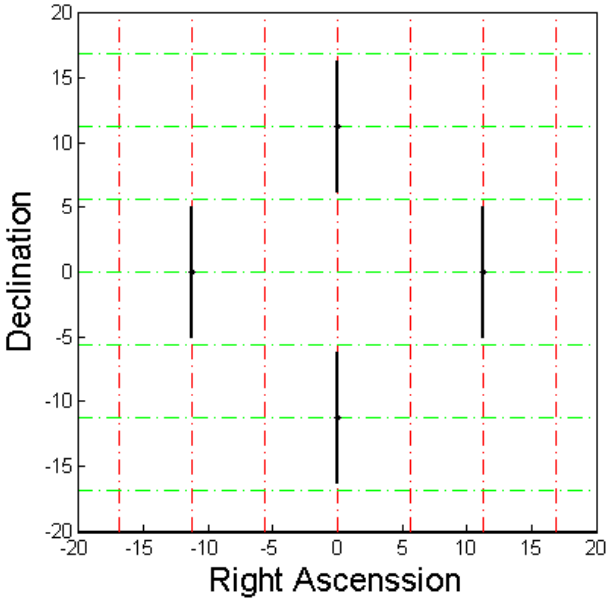
Probability of uniformity ~ $6\ 10^{-5}$

[Hutsemékers, D. 1998]
[Hutsemékers, D., Lamy, H. 2001]; [Jain et al. 2004]; [Cabanac et al. 2005]; [Hutsemékers et al. 2005];

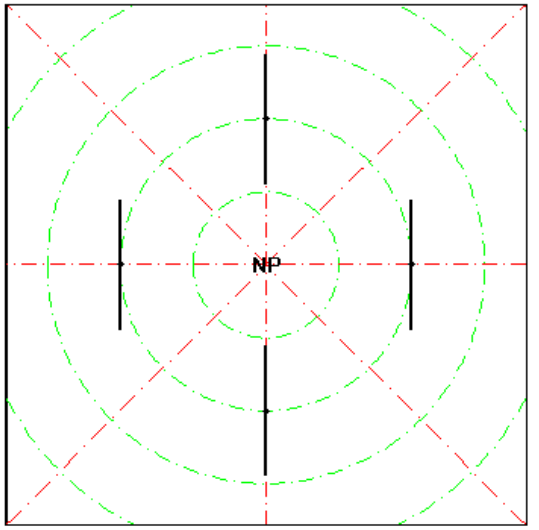
- Full sample : 355 quasars
- Orientation correlations up to ~1 Gpc at $z \approx 1\text{-}2$
- preferred direction ◄► redshift slice

Introduction
Axis dependency

Significance Level ◄► coordinate system



$\psi_{i=1,2,3,4}=0$



$\psi_{1,2,3,4}=\{0,\ 90,\ 0,\ 90\}^{\circ}$

A Coordinate-Invariant Method

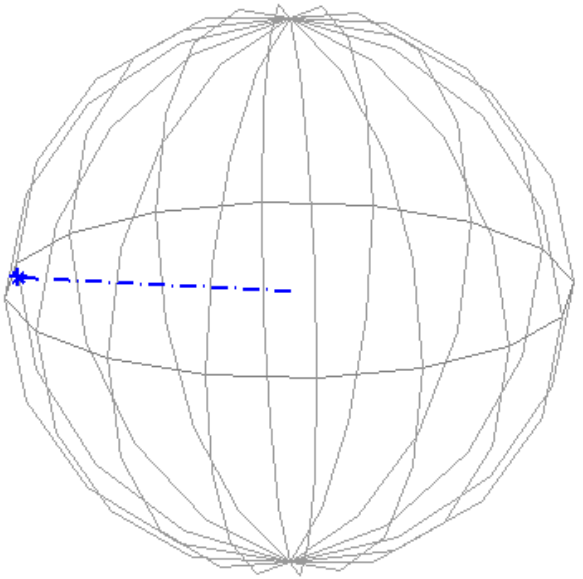
Need for a **coordinate-invariant** **statistical test** that keeps **physical information** and that can be used for **non-uniformly dispersed** sources

Polarisation Space

Cone Algorithm

The Polarisation Space

Physical information: electric field oscillation direction in 3D
1 data point = 1 line of sight + 1 polarisation angle in the orthogonal plane



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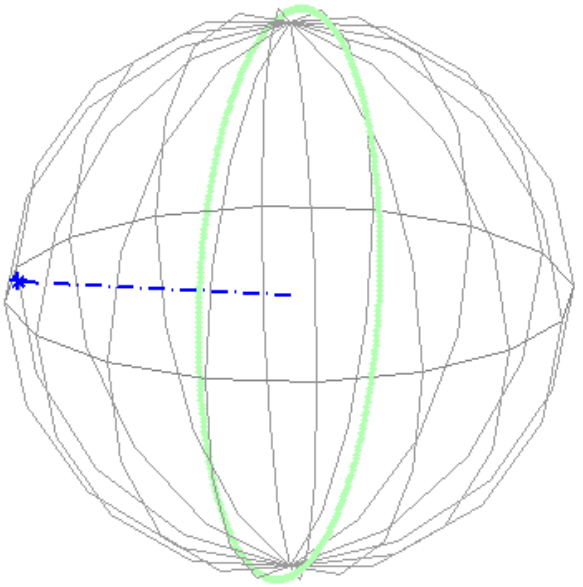
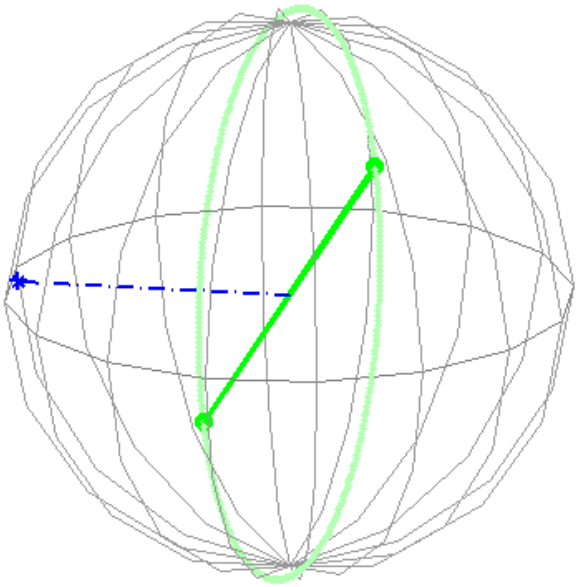


The Polarisation Space

The polarisation space = unit 2-sphere
Polarisation “vectors„ regarded as points on the polarisation space

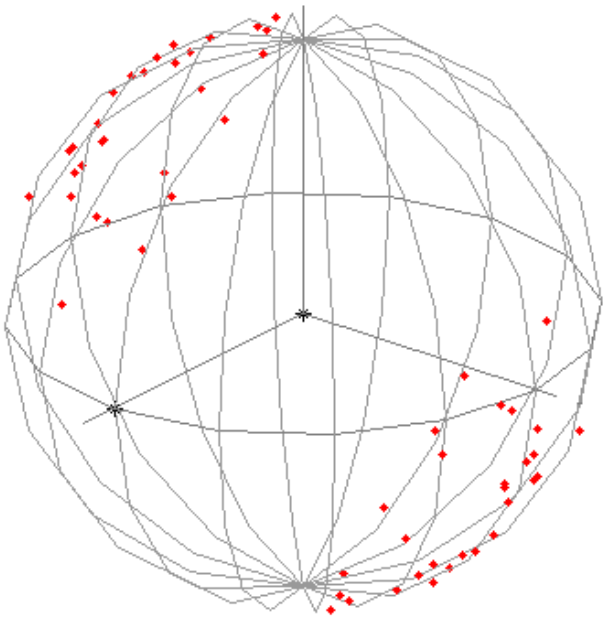


Polarisation axes: circular data ➡ spherical data

The Polarisation Space

Polarisation “vectors„: spherical data
Configuration ◄► density of polarisation points with spherical caps of equal area

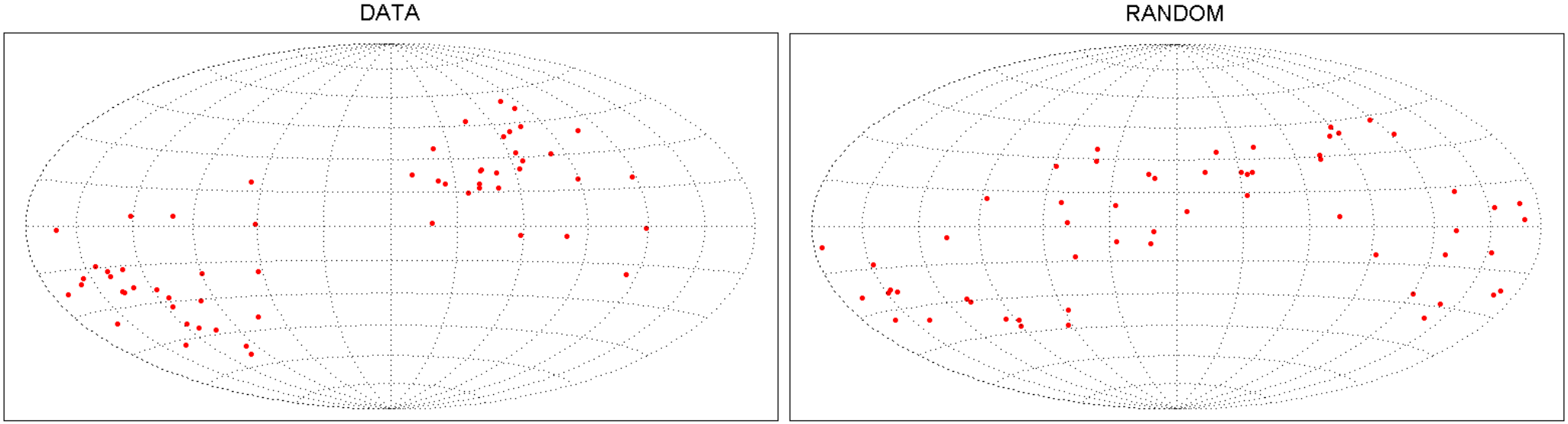
(half aperture angle η)



Polarisation space for the A3 region
from [Hutsemékers et al. 2005]

The Polarisation Space

Polarisation “vectors„: spherical data

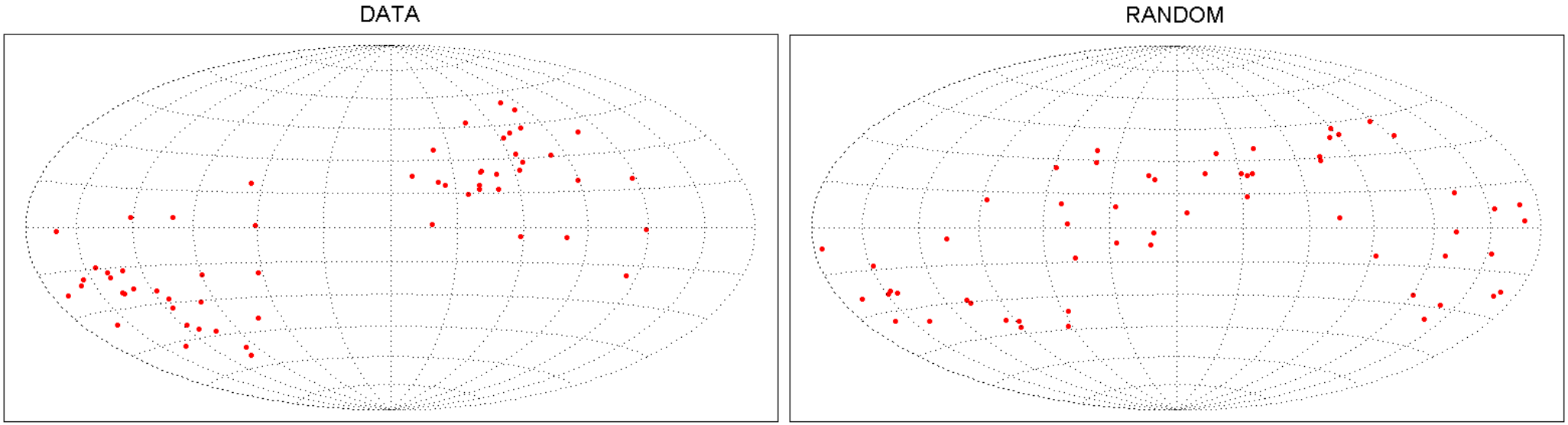


Polarisation space for the **A3 region** from [Hutsemékers et al. 2005]

How to distinguish unexpected densities of polarisation points from “natural„ ones, i.e, drawn from a uniform distribution?

The Polarisation Space

Polarisation “vectors“: spherical data



Polarisation space for the **A3 region** from [Hutsemékers et al. 2005]

How to distinguish unexpected densities of polarisation points from “natural„ ones, i.e, drawn from a uniform distribution?

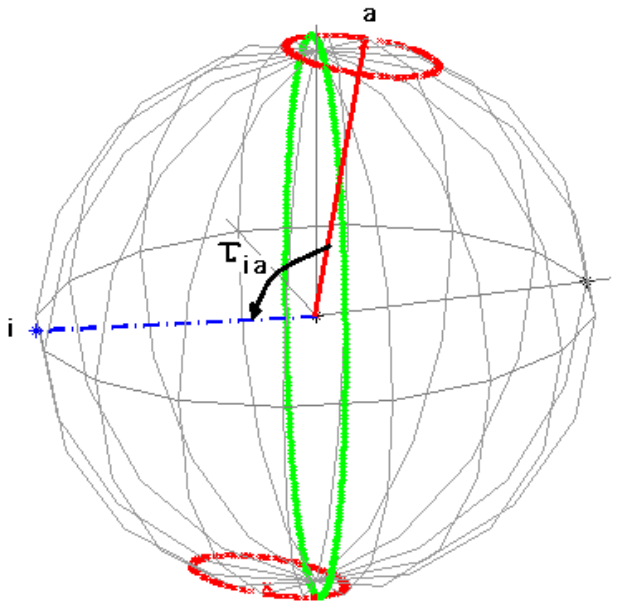
➡ Cone Algorithm

The Cone Algorithm

1) Cones of fixed half aperture angle η

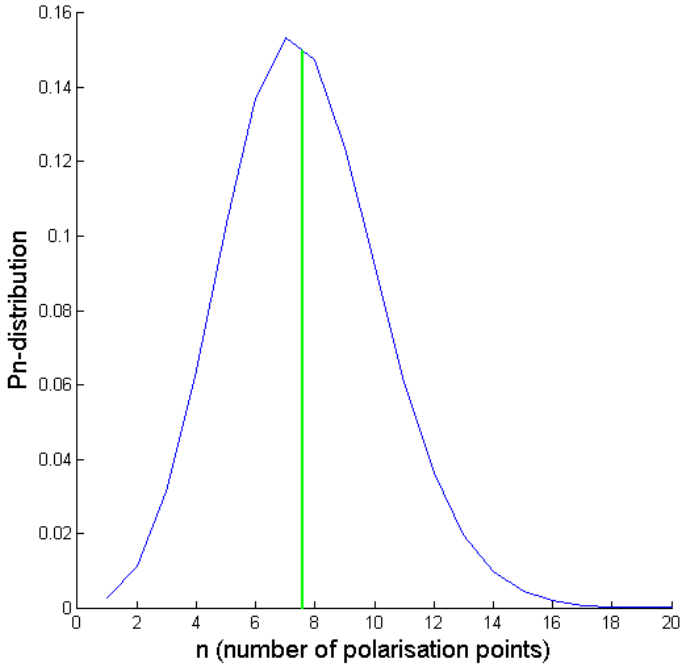
2) Analytical individual probability p_{ia}

$$p_{ia} = \frac{arc-length_{ia}}{\pi} \propto f\left(\eta,\ \tau_{ia}\right)$$



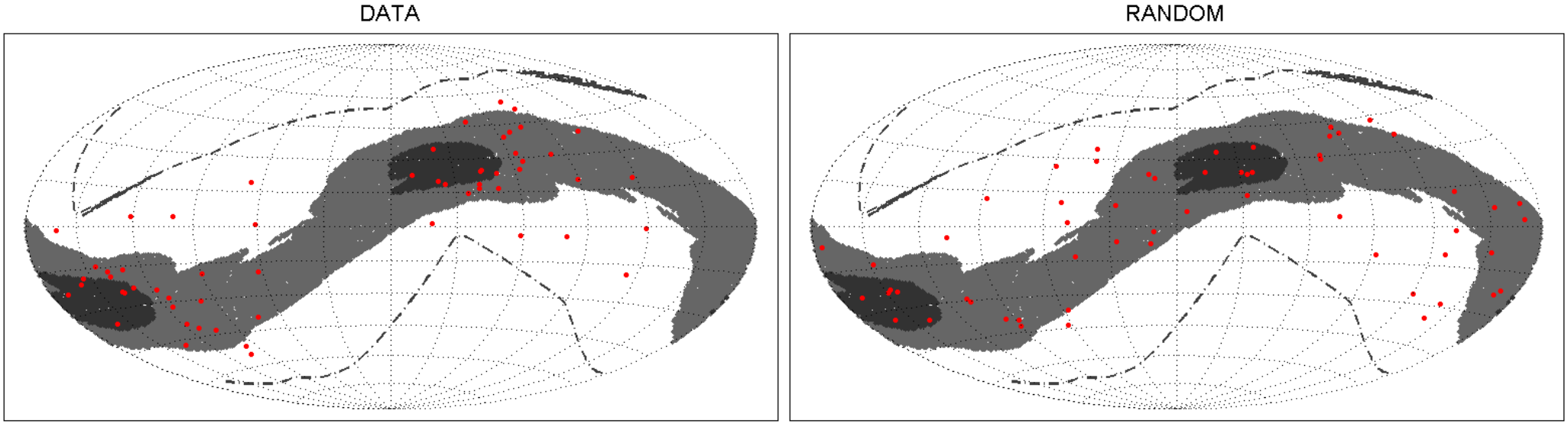
The Cone Algorithm

1) Cones of fixed half aperture angle η
2) Analytical individual probability p_{ia}
3) Recursive algorithm gives probability distribution P_n^a



Polarisation Map

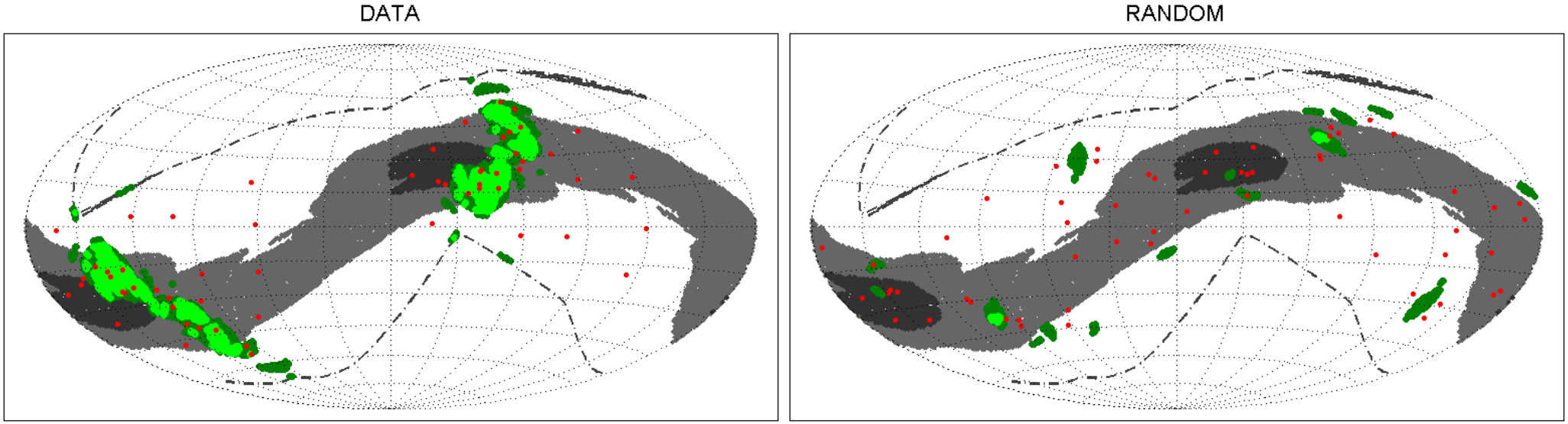
Expected Background



Polarisation space for the **A3 region** from [Hutsemékers et al. 2005]

Polarisation Map

Observations v.s. Expected Background

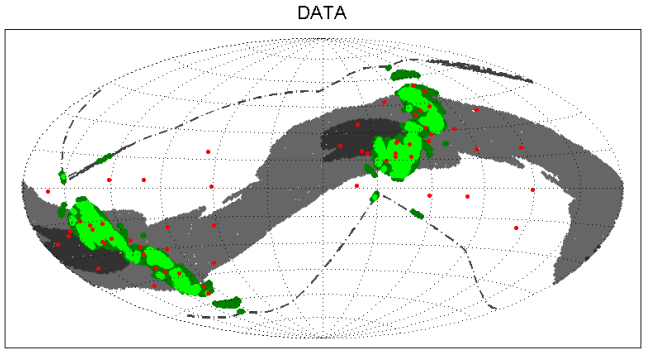


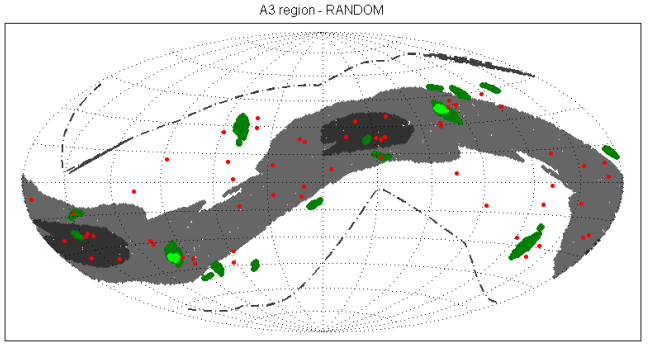
Polarisation space for the **A3 region** from [Hutsemékers et al. 2005]

- At least 3σ deviation in number of polarisation points
- At least 2σ deviation in number of polarisation points

Polarisation Map

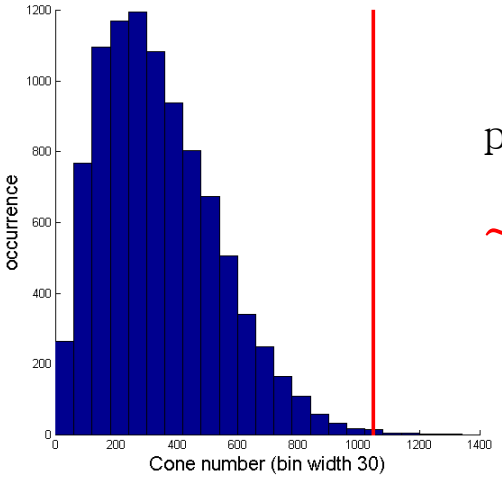
Observations v.s. Expected Background





Polarisation space for the **A3 region** from [Hutsemékers et al. 2005]

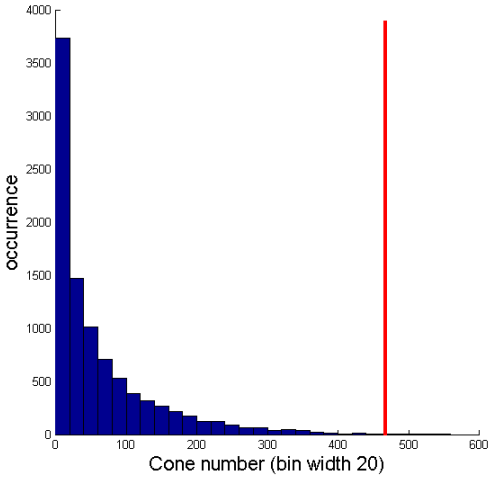
● 2σ



p-value :

~ 0,23%

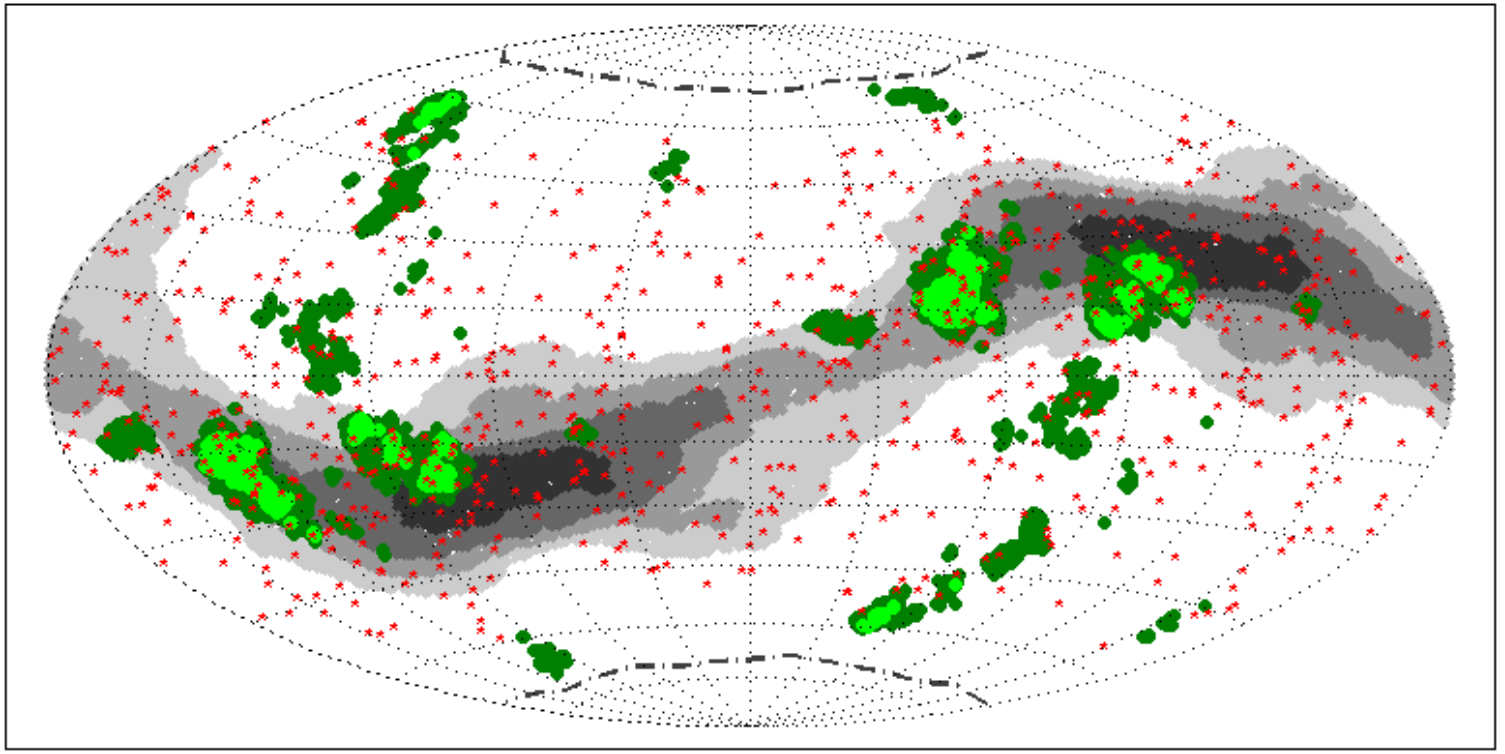
● 3σ



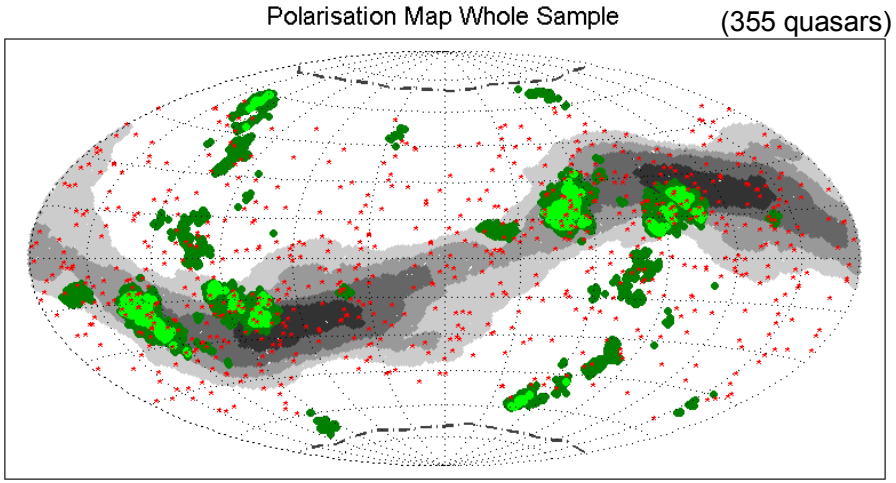
p-value :

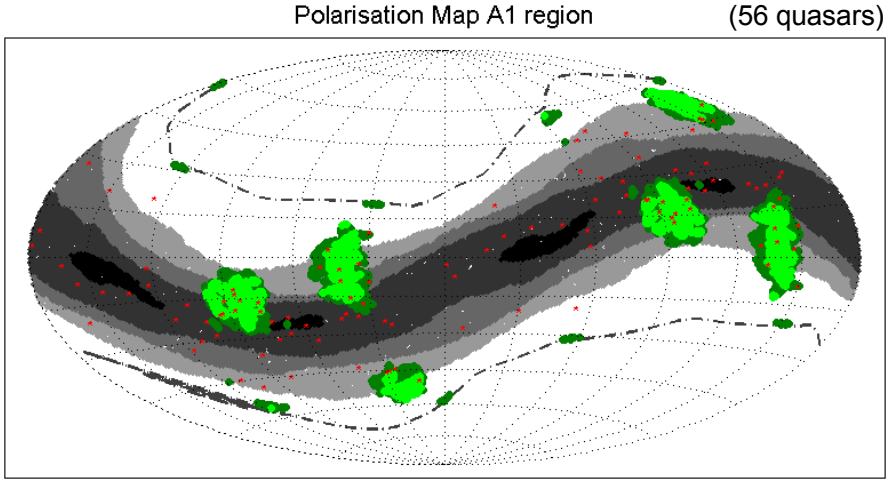
~ 0,14%

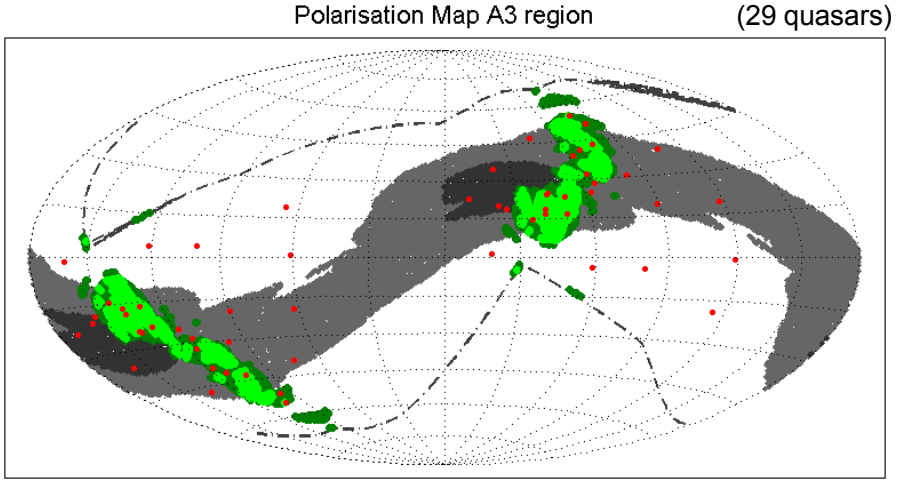
Polarisation Map Whole Sample (355 quasars)



- At least 3σ deviation in number of polarisation points
- At least 2σ deviation in number of polarisation points



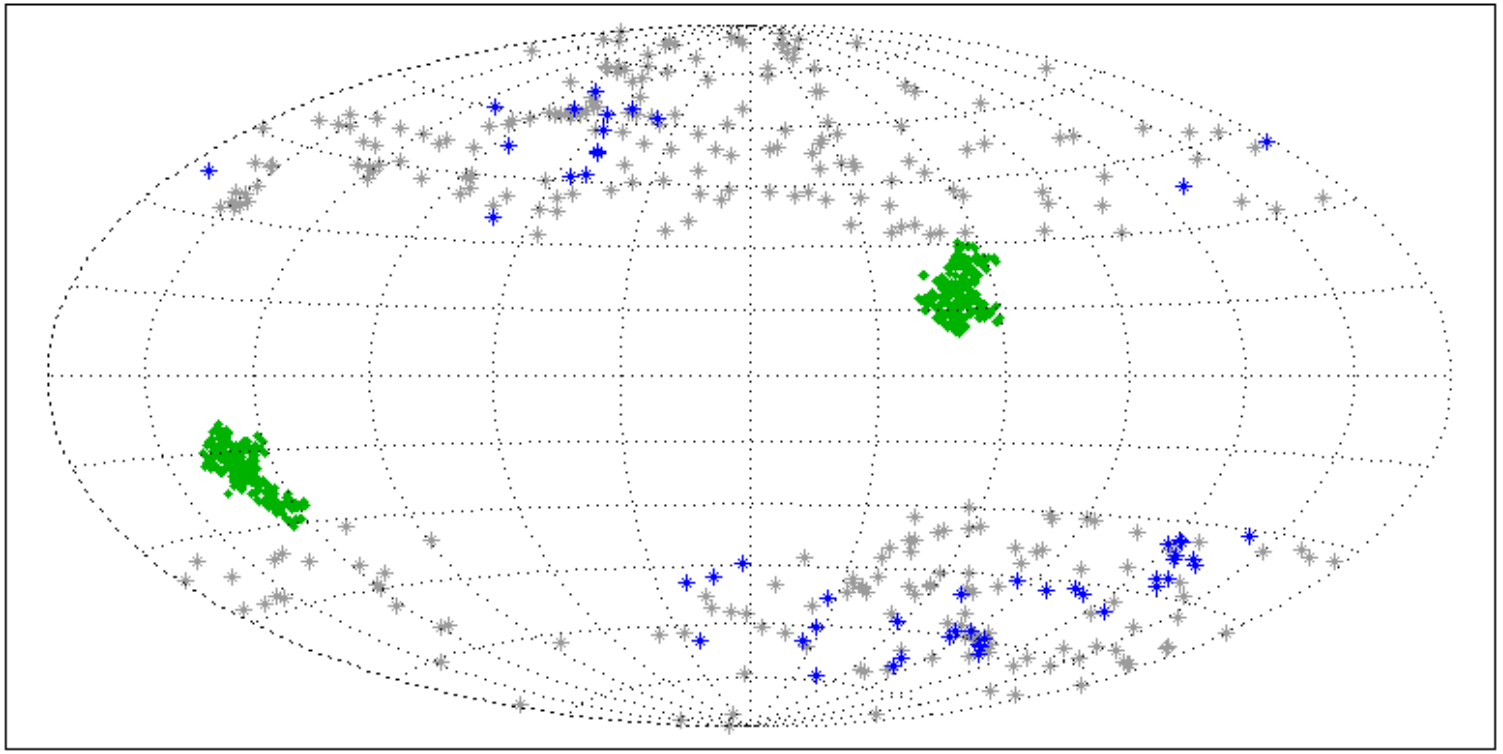




Polarisation space for the **A1 and A3 regions** from [Hutsemékers et al. 2005]

- At least 3σ deviation in number of polarisation points
- At least 2σ deviation in number of polarisation points

Sensitivity to the Antipodal Correlation

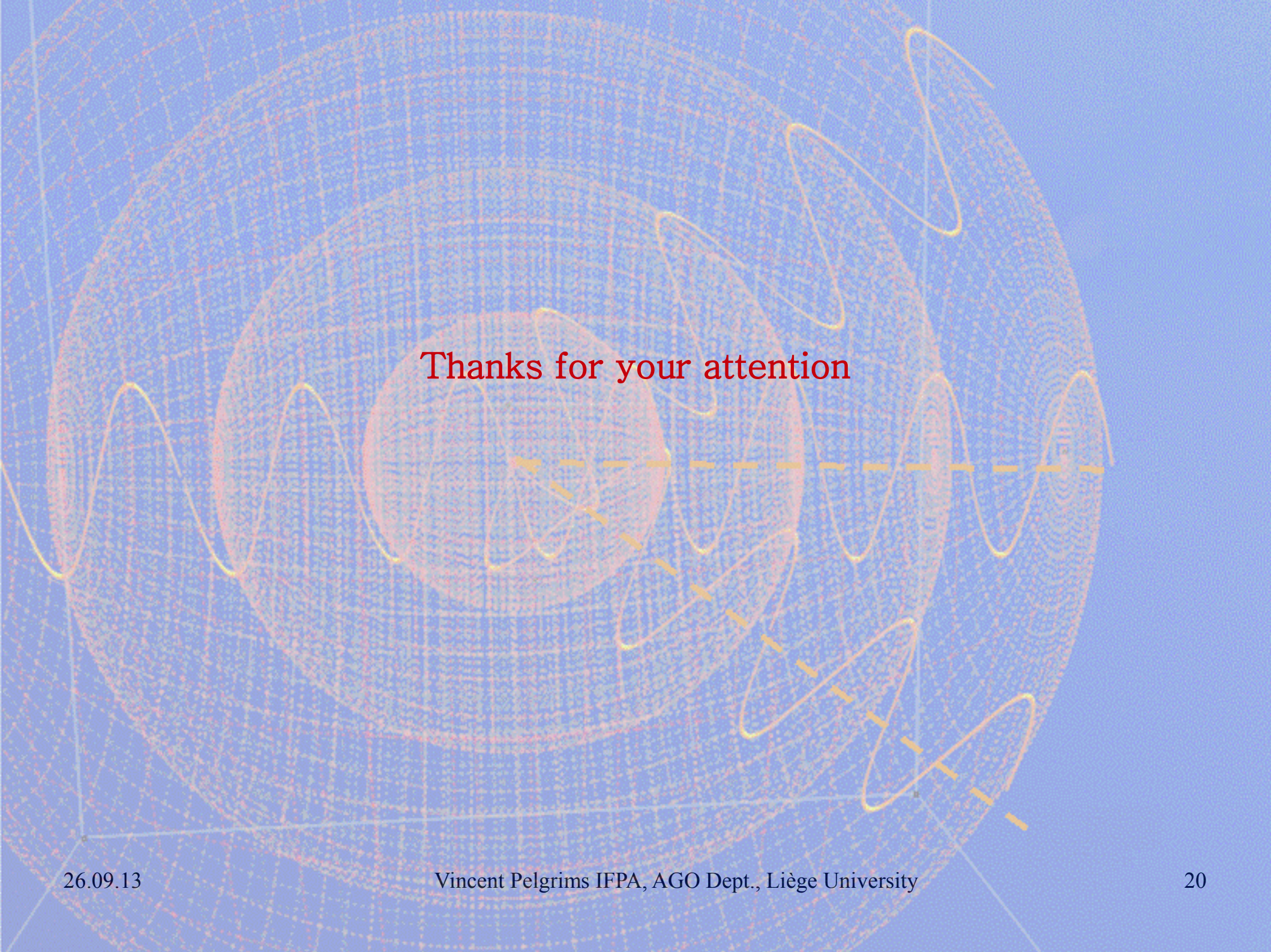


Conclusion

- a coordinate-invariant method
- confirmation of anisotropies on polarisation orientations
- objective cuts on physical parameters (RA, dec, z, p_lin)
- preferred axis definition
- probe the geometry of the signal

DIRECT PROBE OF PHYSICS STANDING BEHIND THE ANISOTROPIC ORIENTATIONS OF LINEAR POLARISATIONS OF QUASAR LIGHT

Soon in [Pelgrims V. & Cudell J.R. (2013)]


Thanks for your attention

References

- Hutsemékers, D. 1998, A&A, 332,410
- Hutsemékers, D., Lamy, H. 2001, A&A, 367, 381
- Hutsemékers et al., 2005, A&A, 441, 915
- Jain, P., Narain, G., Sarala, S. 2004, MNRAS, 347, 394
- Cabanac et al., 2005, ASP Conf. Series

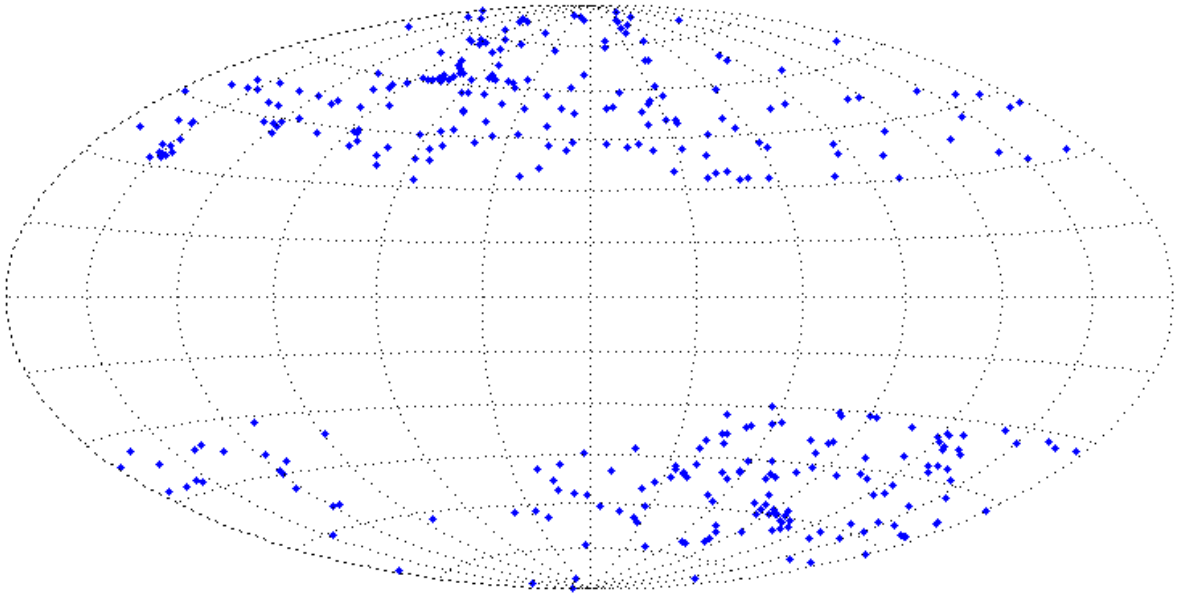
Annex

Perspectives of application this method to :

- Radio Sources
- CMB Polarisation (Planck)
- ...

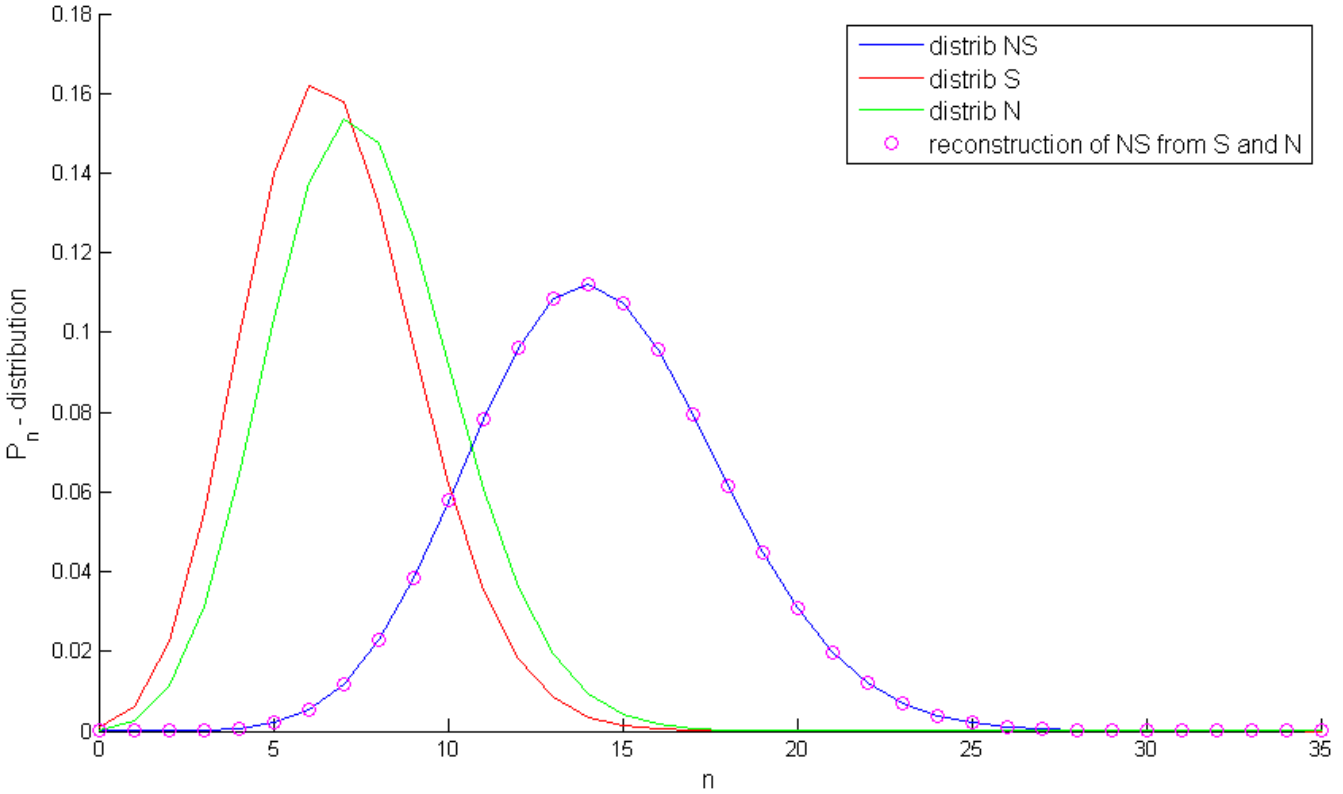
Annex

The whole sample of 355 quasars



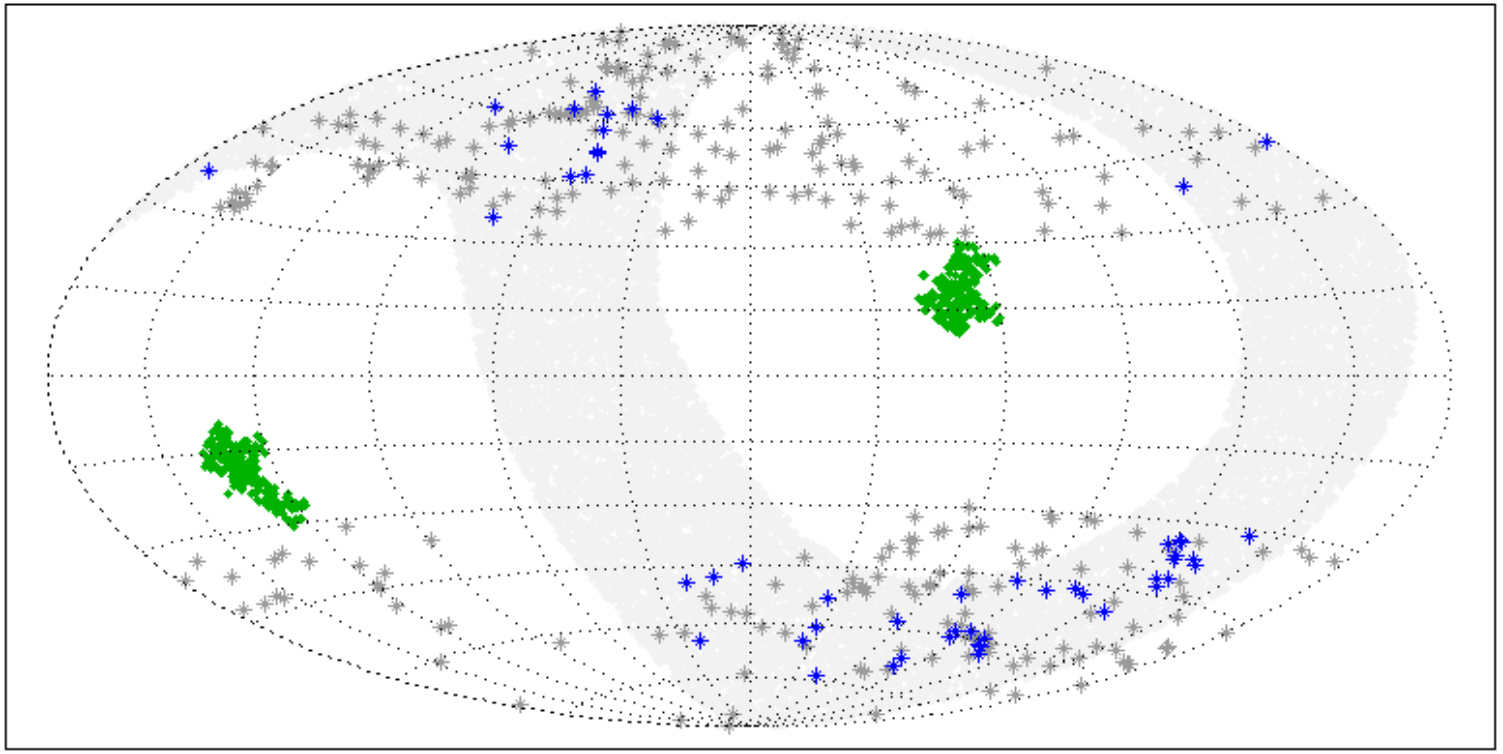
Annex

Convolution North-South



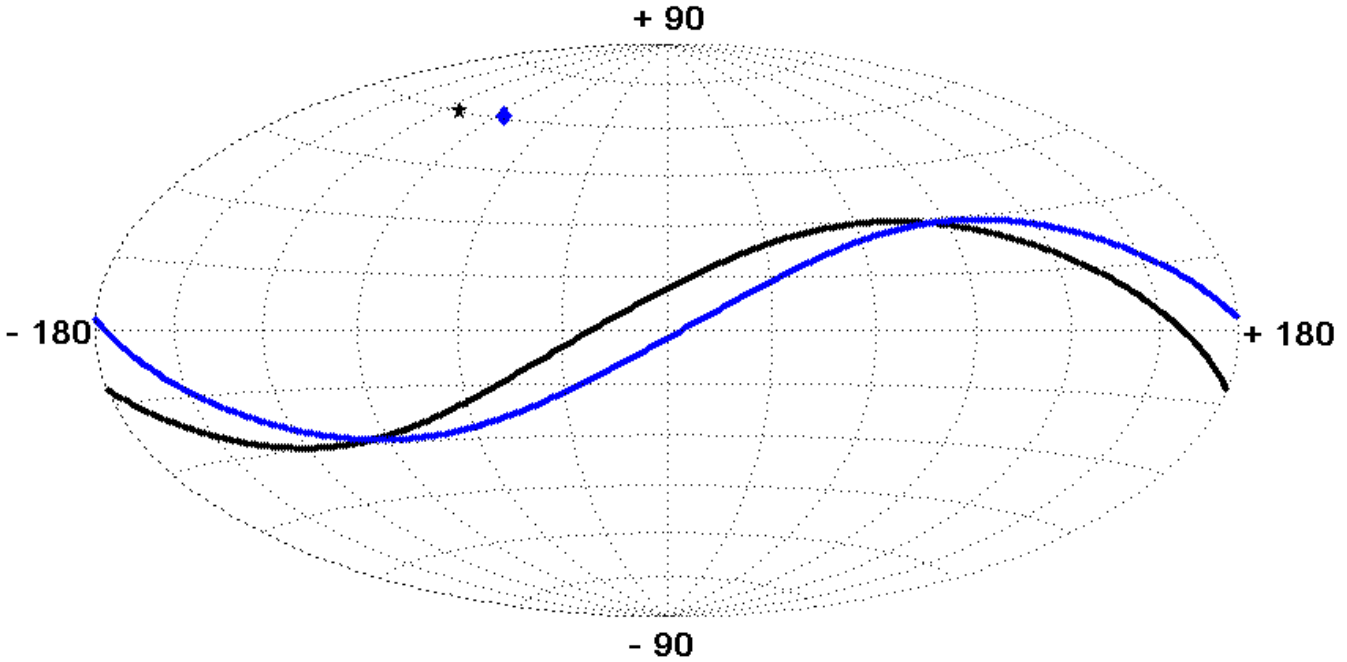
Annex

Correlation North-South and sensitive girdle



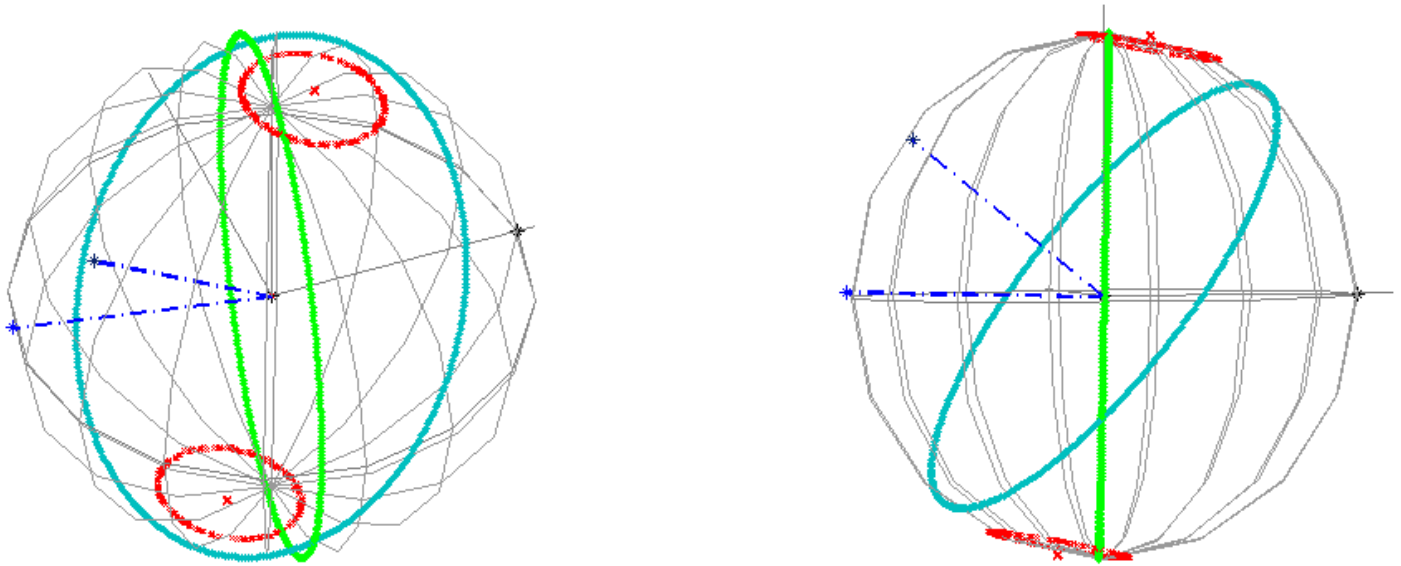
Annex

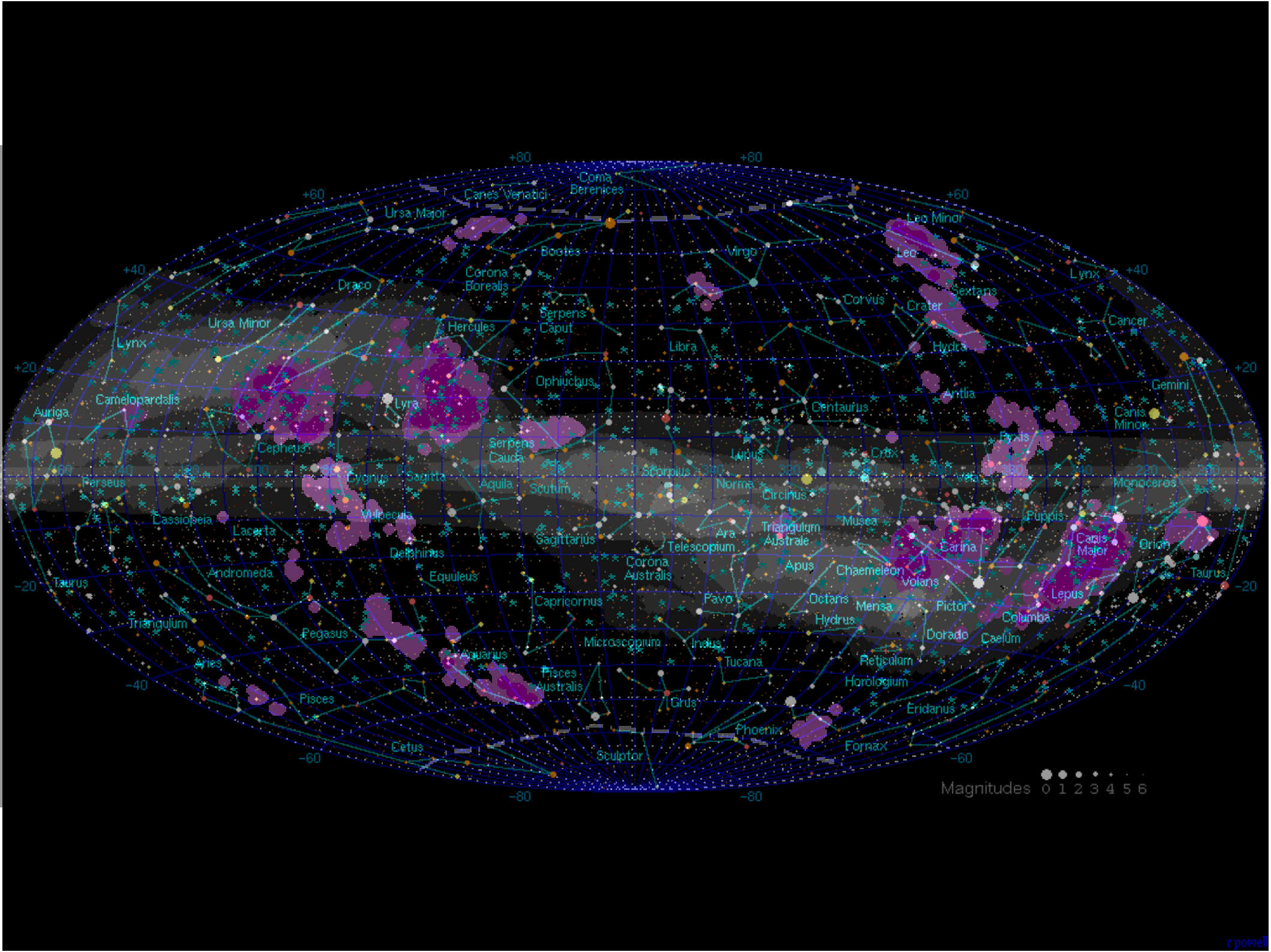
Geometrical locii, the case of 2 quasars



Annex

Individual probabilities, the case of 2 quasars and one cone




+80
+60
+40
+20
-20
-40
-60
-80
Coma Berenices
Canes Venatici
Ursa Major
Leo Minor
Leo
Virgo
Lynx
Boötes
Corona Borealis
Draco
Sextans
Corvus
Crater
Ursa Minor
Hercules
Serpens Caput
Cancer
Lynx
Libra
Hydra
Ophiuchus
Gemini
Camelopardalis
Auriga
Lyra
Centaurus
Antlia
Canis Minor
Pyxis
Cepheus
Serpens Cauda
Lupus
Crux
Scorpius
Norma
Monoceros
Perseus
Cygnus
Sagitta
Aquila
Scutum
Circinus
Vulpecula
Puppis
Cassiopeia
Lacerta
Triangulum Australe
Musca
Ara
Sagittarius
Telescopium
Carina
Canis Major
Orion
Delphinus
Corona Australis
Apus
Chamaeleon
Andromeda
Equuleus
Volans
Taurus
Capricornus
Pavo
Octans
Mensa
Pictor
Lepus
Triangulum
Hydrus
Columba
Pegasus
Microscopium
Indus
Dorado
Caelum
Aquarius
Tucana
Reticulum
Aries
Pisces Australis
Horologium
Pisces
Grus
Eridanus
Phoenix
Fornax
Cetus
Sculptor
Magnitudes 0 1 2 3 4 5 6